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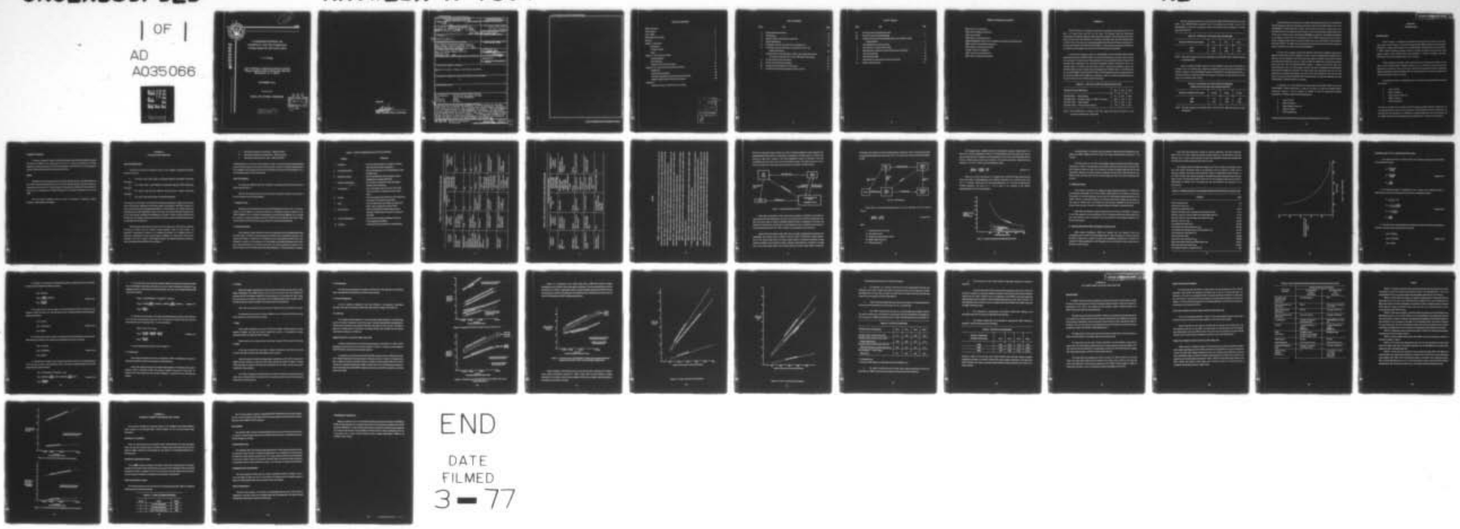

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A COMPARISON BETWEEN THE AN/ARN-84(V) AND THE AN/ARN-118(V) TACANS, BASED ON LIFE CYCLE COSTS.

L. A. Cundari

Naval Weapons Engineering Support Activity
Weapon Systems Analysis Department (ESA-19)
Washington, D. C. 20374

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TACAN (Tactical Air Navigation) equipments are being procured for the Navy, Coast Guard, and Air Force. The life-cycle costs and performance characteristics of different models of these equipments vary greatly. The two equipments currently being procured are the AN/ARN-84(V), for the Navy and Coast Guard, and the AN/ARN-118(V) for the Air Force. This report is a cost analysis based on the life cycles of these two equipments. It provides data intended to aid NAVAIR and OPNAV in making future procurements cost effective and responsive to both peacetime and war time TACAN equipment requirements.

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ABBREVIATIONS AND GLOSSARY

BITE. Built-In Test Equipment

DME. Distance Measuring Equipment

LOR. Level of Repair

MTBF. Mean time between failures

Organic Maintenance. Repair at the immediately responsible organizational level

PGSE. Peculiar Ground Support Equipment

RIW. Reliability Improvement Warranty

TACAN. Tactical Air Navigation

VAST. Versatile Avionics Shop Test

WRA. Weapon Replaceable Assemblies

SUMMARY

TACAN (Tactical Air Navigation) equipments are presently being procured for the U.S. Navy, U.S. Coast Guard, and the U.S. Air Force. The life-cycle costs and performance characteristics of different models of these equipments vary greatly. The two equipments currently being procured are the AN/ARN-84(V), for the Navy and Coast Guard, and the AN/ARN-118(V) for the Air Force. This report is a cost analysis based on the life cycles of these two equipments. It provides data intended to aid NAVAIR and OPNAV in making future procurements cost effective and responsive to both peace time and war time TACAN equipment requirements.

A life-cycle cost analysis of both the AN/ARN-84(V) and the AN/ARN-118(V) TACAN equipments proves the AN/ARN-118(V) to be the more economical of the two, both to procure and to maintain. The life-cycle cost differential between the two equipments remains in favor of the AN/ARN-118(V) regardless of the maintenance philosophy selected. Furthermore, there is no crossover point in life-cycle costs since there is both a lower initial acquisition cost for the AN/ARN-118(V) and also a higher mean-time-between-failure (MTBF) rate for it. The MTBF rates for the AN/ARN-84(V) and the AN/ARN-118(V) TACAN equipments presently being procured by the military are 500 hours and 800 hours, respectively. Table S-1 provides a comparative listing of life-cycle costs for the two TACAN equipments analyzed.

TABLE S-1. LIFE-CYCLE COST PER OPERATING UNIT ($K)

TACAN and Type of Maintenance	10 yr	12 yr	15 yr
AN/ARN-84(V) – Existing Organic	24.1	26.4	29.8
AN/ARN-118(V) – Contractor Repair–to 1982–Then Organic	20.8	21.9	23.7
AN/ARN-118(V) – Totally Organic	19.0	20.6	23.1
AN/ARN-118(V) – Totally Contractor Repair	17.0	18.4	20.5

NOTE: The AN/ARN-84(V) is presently under total organic maintenance; therefore, no other maintenance consideration is appropriate.

The Navy estimates indicate it will buy more than 2,000 TACAN equipments by the year 1982. If the AN/ARN-118(V) equipment were to be procured by the Navy in lieu of the AN/ARN-84(V), a potential cost savings in excess of $12 million could be realized for a 15-year period (see Table S-2).

TABLE S-2. POTENTIAL LIFE-CYCLE COST SAVINGS ($M)

Number of TACAN to be Procured	10 yr	12 yr	15 yr
1000	3.30	4.50	6.10
2000	6.60	9.00	12.20

NOTE: These data are based on both the AN/ARN-84(V) and AN/ARN-118(V) TACANs achieving the specified MTBF.

Failure to achieve the MTBF figure for the AN/ARN-84(V) will increase the difference in life-cycle costs. The following data indicate the magnitude of the life-cycle cost difference (in *millions of dollars) if the* AN/ARN-84(V) *achieves a field* MTBF of only 400 operating hours. If data was utilized for the AN/ARN-118(V) under organic maintenance, the results would be more in favor of the AN/ARN-118(V) TACAN.

TABLE S-3. POTENTIAL LIFE-CYCLE COST SAVINGS ($M)
BASED ON THE AN/ARN-118(V) PROJECTED MTBF

Number of TACANs to be Procured	10 year	12 year	15 year
1000	4.70	5.90	7.80
2000	9.40	11.80	15.60

NOTE: This data is based on the AN/ARN-118(V) under RIW until 1982 then shifting to organic maintenance.

The Coast Guard has a requirement to replace 193 outdated AN/ARN-21 and AN/ARN-52 TACAN equipments. They have requested that the Navy procure the AN/ARN-118(V) in lieu of the AN/ARN-84(V) TACAN equipment presently under contract for Navy use. Procurement of the AN/ARN-118(V) for the Coast Guard would result in a life-cycle cost savings of approximately $7.5 million over a 15-year period or approximately $38,860 per equipment. The apparent discrepancy in cost savings of $7.5 million for replacement of 193 TACAN equipments and that of $12.2 million afforded the Navy for the purchase of 2,000 units is due to the Peculiar Ground Support Equipment (PGSE). This PGSE would be required by the Coast Guard to equip 30 of its bases for organic maintenance of the Navy-procured AN/ARN-84(V).

The Air Force is presently procuring the AN/ARN-118(V) under a Reliability Improvement Warranty (RIW) contract which is designed to ensure a mean-time-between-failure (MTBF) rate of 800 hours for the equipment within four years after award of contract (this incentive contract encourages the contractor to strive for a minimum MTBF of 1000 hours in the same time period). Should the Navy enter the AN/ARN-118(V) program, it would be at least two years after commencement of this Air Force program, and thus, two years of reliability and maintainability data would be available for evaluation. The Coast Guard could also benefit from the Air Force experience by obtaining repair service from the Air Force after completion of the four-year RIW period. Any plan to procure AN/ARN-118(V) TACANs would not require the replacement of those AN/ARN-84(V) TACANs currently in the system.

In conclusion, it is recommended that the Navy procure the AN/ARN-118(V) in lieu of the AN/ARN-84(V) TACAN equipments. In order for the Navy to procure the AN/ARN-118(V) equipments, however, it will be necessary for OPNAV to relax the requirements presently prescribed for TACAN by deleting the following features:

- Inverse TACAN
- DME only Beacon
- Radio Frequency Data Link
- ASW-27 Interface
- VAST compatibility

These features are neither desired nor required by the Coast Guard or the Air Force.

CHAPTER I

INTRODUCTION

BACKGROUND

TACAN (Tactical Air Navigation) equipments have been used by the Navy for more than twenty years and have ranged in unit price from approximately $60 thousand for the experimental XN/ARN-21 in 1952 to $12.4 thousand for the AN/ARN-84(V) (hereafter referred to as the 84(V)) in 1976. TACAN equipments basically function to provide an airborne user with slant range distance, bearing, course right/left data (course deviation), a "to/from" indication, and audio identification of a suitably-equipped station, ship, or aircraft.

TACAN equipments presently under procurement by the services are the 84(V) for the Navy and the AN/ARN-118(V) (hereafter referred to as the 118(V)) for the Air Force. Both equipments are physically similar and are self-contained units equipped with easily transportable Weapon Replaceable Assemblies (WRA). Both are hybrid equipments in that they contain both solid-state components and vacuum tubes.

The equipments differ in characteristics and cost. The 84(V) provides additional functions which include:

a. Inverse TACAN
b. DME Only Beacon
c. Radio Frequency Data Link
d. ASW-27 Interface
e. VAST Compatibility

The costs for the 84(V) and the 118(V) are $12.4 thousand and $9.4 thousand, respectively. It is not anticipated that the unit cost will vary greatly in the foreseeable future and furthermore, it is estimated that the requirement for TACAN as an individual equipment will be eliminated by the year 1990. Therefore, life-cycle costing data is only applicable for a maximum 15-year period.

PURPOSE OF REPORT

This report, prepared for Naval Air Systems Command Code 533, was developed to provide NAVAIR and OPNAV with costing data to aid them in future procurements of TACAN equipments. Costing data make up the life-cycle analysis of this report for the two equipments presently under procurement by the Navy and the Air Force.

SCOPE

The 84(V) currently being procured by the Navy through contract with ASC Systems and the 118(V) currently being procured by the Air Force through contract with Collins Radio are analyzed over a life cycle of 10, 12, and 15 years. This time span is consistent with the estimate that there will be no requirement for TACAN equipment as an individual navigation set by the year 1990.

The cost analysis presented covers the costs of acquisition, maintenance, support equipment, documentation, and logistics.

CHAPTER II

LIFE-CYCLE COST ANALYSIS

ANALYSIS BASELINES

Life-cycle cost analysis is provided for each of four probable maintenance philosophy situations as follows:

a. The 84(V) under totally organic maintenance based on the present maintenance philosophy.

b. The 118(V) under a total Reliability Improvement Warranty (RIW) maintenance philosophy.

c. The 118(V) under RIW until 1982 and then shifting to an organic maintenance philosophy.

d. The 118(V) under totally organic maintenance philosophy.

The rationale for the selection of the different maintenance philosophies is based on the fact that Navy funds have been expended for performing organic maintenance on the 84(V) and there is no need to consider any other maintenance philosophy for this equipment. The 118(V) maintenance philosophy has not been established, however, and funds have not been allocated. Therefore, three of the most practical maintenance philosophies were chosen in order to provide NAVAIR and OPNAV with the necessary costing data to determine which maintenance philosophy would be the most desirable and cost effective.

RIW maintenance philosophy is included in the cost analysis since the Air Force is presently procuring the 118(V) using this incentive contract approach. Under the RIW contract, the equipment is guaranteed to operate in its intended environment for a specified period. An equipment is guaranteed to have a certain degree of reliability for a total of four years from 31 December of the year in which it was accepted. However, the reliability guarantee is equated to mean time between failure (MTBF) and is as follows:

- Equipments produced in the first year — 500 hours MTBF
- Equipments produced in the second year — 625 hours MTBF
- Equipments produced after two years — 800 hours MTBF

A failed equipment is returned to the contractor for repair. The contractor further guarantees that there will be an average turn-around time, within the plant, of 15 days. A liquidated damage penalty can be assessed if the contractor fails to meet the specified turn-around time (see Appendix A for a more detailed discussion of the RIW contract).

COST CATEGORIES

Ten major cost categories have been considered in calculating the life-cycle costs and are as follows (also see Table 1).

Table 2 lists the specific costs for the ten cost-factor categories considered, as a function of the four probable maintenance philosophies.

1. Acquisition Costs.

Acquisition costs include the costs of the TACAN equipment and costs, if any, to modify an aircraft for the installation. In the case of the 84(V), no modification costs are required. For the 118(V), $1000 per unit is included for modifications to the aircraft and $500 per unit is included for a converter to change the digital output from ARINC format to DIGITAL Navy format. These costs are based on actual contract prices and estimates for the required modifications.

2. Initial System Spares.

Initial equipment spares include the costs to purchase spare units or subassemblies for base and depot stock. The 84(V) is being procured by the Navy and is maintained by the Navy on an organic basis (Figure 1). When trouble is detected by built-in test equipment (BITE), the unit is replaced by a spare unit. The removed unit is then tested at the base/intermediate level to verify that a failure has occurred. If no failure is found, the unit is sent to base stock as a spare unit. If a failure is found, the unit is tested to isolate the failed subassembly. A failed subassembly is replaced,

TABLE 1. COST CATEGORIES FOR LIFE-CYCLE COSTING

Category	Definitions
1. Acquisition	Cost to purchase equipment, includes any modifications required to aircraft or equipment.
2. Initial System Spares	Cost to purchase spare units or subassemblies for base and depot stock.
3. Replacement Spares	Cost to purchase spare units for discard at failure. Subassemblies to replace failed items.
4. Equipment Maintenance	Cost of labor and material for base, intermediate, and depot level maintenance.
5. Transportation	Cost to ship WRA to/from contractor under RIW. Cost to ship WRA or subassembly to/from base to depot.
6. Training	Cost to train government personnel in the maintenance and support of the equipment and PGSE.
7. PGSE	Cost to purchase base, intermediate, and depot level PGSE. Cost to operate and maintain PGSE.
8. Documentation	Cost to purchase documentation associated with operation, maintenance, and support for equipment and PGSE.
9. Inventory Management	Cost to provide inventory management functions for the equipment and PGSE.
10. RIW Price	Annual price paid to contractor for providing RIW.

TABLE 2. COST FACTORS IN LIFE-CYCLE COST ANALYSIS

Cost Factor Categories	Probable Maintenance Philosophies AN/ARN-84(V) Organic Maintenance	AN/ARN-118(V) RIW	AN/ARN-118(V) RIW until 1982 Organic Maintenance after 1982	AN/ARN-118(V) Organic Maintenance
Acquisition Costs/ Unit ($K) (See note 1)	20.1 Hoffman 13.7 ASC Systems 12.4 ASC Systems Option	10.9	10.9	10.9
Spares/operation unit (%) (See note 2)	19.5%	14%	14%	15%
Spares Cost/ Operation Unit ($K)	3.92 Hoffman 2.67 ASC Systems	1.41	1.41	1.64
Replacement Spares (See note 3)	3%/year	None included in RIW price	1.5%/year	2%/year
Equipment Maintenance (See note 4)	See Figure 4	Included in RIW price	a) Included in RIW price b) See Figure 4 for data after 1982	See Figure 4
Transportation	Included in equipment maintenance item	Average $32 per one-way trip	a) Average $32 per one-way trip RIW b) Included in equipment maintenance cost	Included in equipment maintenance cost
Total Training (See note 5)	180K + 1 person/year/ base for 2 weeks cost $600/week	1 person/year/base for 1 week cost $600/week	a) 1 person/year/base for 1 week b) 1 person/year/base for 2 weeks cost $600/week	1 person/year/base for 2 weeks cost $600/week

TABLE 2. COST FACTORS IN LIFE-CYCLE COST ANALYSIS (Continued)

Cost Factor Categories	Probable Maintenance Philosophies: AN/ARN-84(V) Organic Maintenance	AN/ARN-118(V) RIW	AN/ARN-118(V) RIW until 1982 Organic Maintenance after 1982	AN/ARN-118(V) Organic Maintenance
PSGE (See note 6) ($)	15,000 per base $3.4M in Intermediate & Depot	5,000 per base	$5,000 per base under RIW 15,000 per base under organic $3.6M in intermediate & depot	15,000 per base $3.6M in intermediate & depot
PSGE Support	3%/year	3%/year	3%/year	3%/year
Data Publications ($)	748K + 1% of acquisition cost/unit	$425/operational unit	a) $425 operational unit b) 5% of acquisition cost/unit	6% of acquisition cost/unit
Inventory Management Cost ($)	Included in equipment maintenance costs	Included in RIW price	a) Included in RIW price b) Included in equipment maintenance costs	Included in equipment maintenance costs
RIW price/year ($/year) (See note 7)	None	4.7% of $9.9K = 0.47K$/yr until 1982 After 1982 - 5.45%/year	$.47K/year until 1982	None

NOTES

NOTE 1. The $20.1K price (Hoffman Electronics) is for an ongoing procurement of 151 sets. The $13.7K price is for an ongoing procurement (ASC Systems) for 119 units. The $12.4K price is for a recently-exercised option to procure 123 additional units from ASC Systems. The unit price under RIW is based on an Air Force contract price of $9.4K plus $1.0K for aircraft modifications and $0.5K for a converter to change the digital output from ARINC format to Navy DIGITAL format.

NOTE 2. These data are based on the MTBF [500 operating hours stated for AN/ARN-84(V) and 800 operating hours for the AN/ARN-118(V)], a spares sufficiency rate of 95 percent, and normal pipeline times used for organic or warranty maintenance. These pipeline times for organic maintenance and warranty maintenance are described in Appendix B.

NOTE 3. Replacement spares estimates are based on MTBF and the replacement rates based on the Level of Repair analysis.

NOTE 4. These estimates include base, intermediate, and depot maintenance. Factors for base, intermediate, and depot maintenance are provided in Table 2.

NOTE 5. The $180K in training for AN/ARN-84(V) has already been invested. Training under organic maintenance is based on one person/year/base for two weeks. Price is $600/week/person in 1976 dollars.

NOTE 6. The $3.4M in intermediate and depot PGSE has already been invested for the AN/ARN-84(V). It is estimated that $200K will be required in PGSE and software (above what has already been invested) to accommodate the AN/ARN-118(V).

NOTE 7. A RIW price of 4.7 percent per year would apply through 1982. After 1982, price would increase in line with inflation statistics. An inflation rate of five percent is used in estimating price escalation after 1982. Additionally, the 4.7 percent can increase before 1982 if the average rate of inflation exceeds five percent. There is no guarantee that RIW can be extended beyond 1982 if the contractor is unwilling.

and the unit returned to base unit stock as a spare. The failed subassembly is either repaired at the base/intermediate level and sent to base stock or forwarded to the depot where it is repaired, and returned to base stock. However, if the failed subassembly cannot be identified at the base intermediate level, the entire unit is sent to the depot for repair. The depot repairs the unit and returns it to base stock. Typical total turnaround time for the 84(V) TACAN is 45 days.

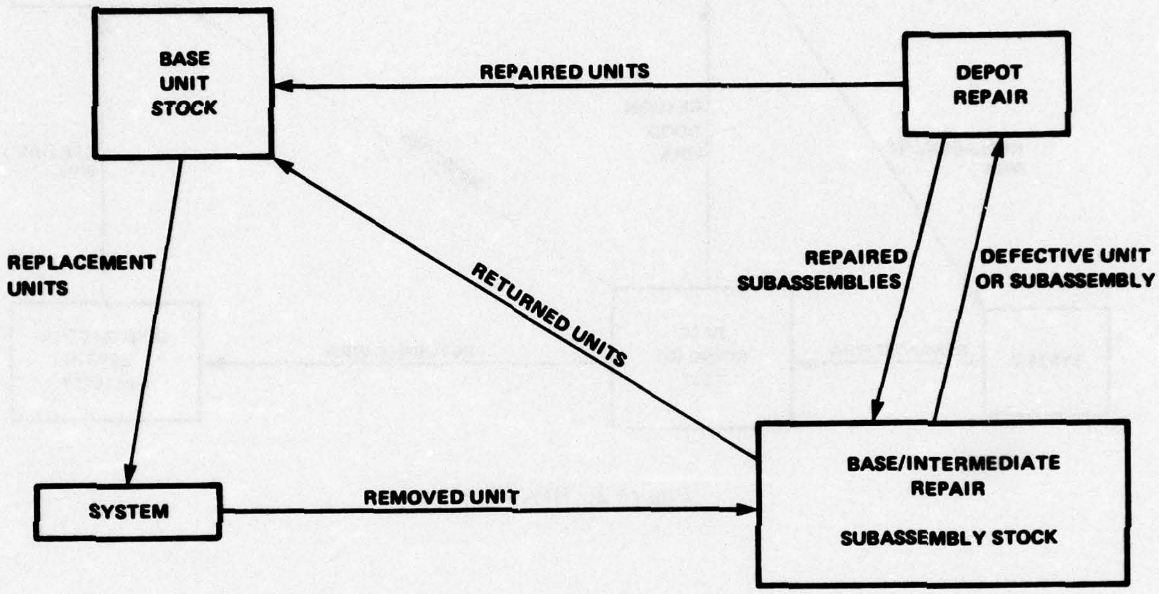

Figure 1. Organic Maintenance Pipeline

Under organic maintenance, initial system spares are based on the MTBF of the equipment, a spares sufficiency rate of 95 percent, and a normal turnaround time of 45 days. Additionally, each base must have at least one weapon replaceable assembly (WRA) or subassembly of each type. The estimate of initial spares is 19.5 percent of initial acquisition cost for the 84(V) and 15 percent of the initial acquisition cost for the 118(V). Inflation is not considered in these estimates.

Figure 2 shows the pipeline under RIW. Since no military maintenance is performed at the subassembly level, sparing is only for WRA's. Under the 118(V) TACAN RIW, a repaired WRA is sent to the central supply depot. The central supply depot is a contractor-maintained, bonded storeroom located at the contractor's facility. Generally, replenishment is initiated by a message sent to the central supply depot from the base requiring the spare. Rapid reaction reduces the

turnaround time as seen by the user to approximately 12 days (0.4 month). Initial spares are based on an achievable average total turnaround time of 1.5 months and a spares sufficiency probability of 0.95.

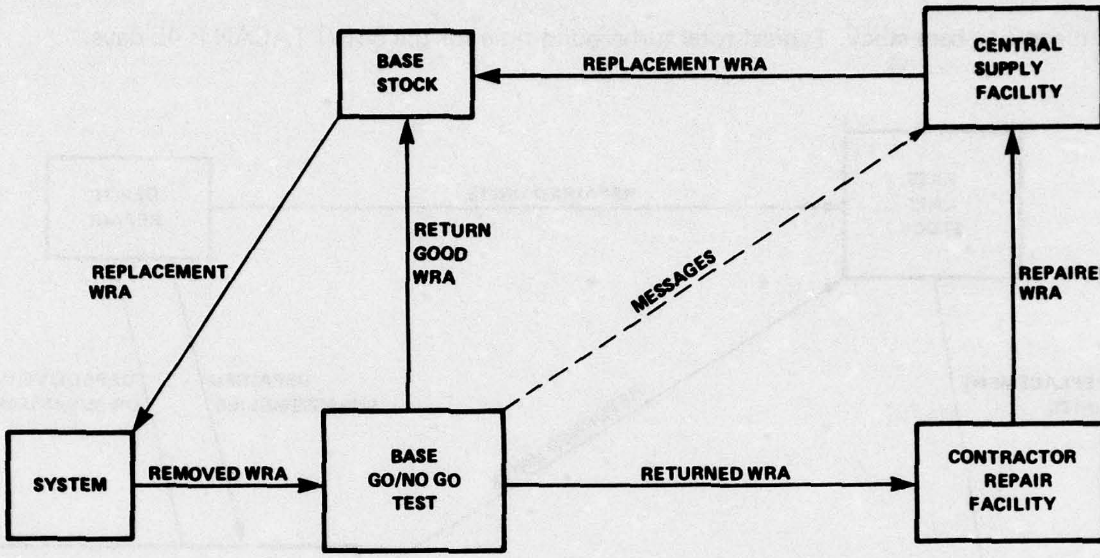

Figure 2. RIW Pipelines

Under RIW, the required spares/operational unit can be calculated from the following formula:

$$\frac{\text{Spares}}{\text{Op Unit}} = \frac{TGH}{M(1-R)} \qquad \text{Equation 10.1}$$

where

T = Turnaround time (in months)

G = Ground-to-air ratio

H = Flight hours per aircraft per month

M = MTBF (operating hours)

R = False removal rate

From historical data, it appears that G and R are basically constants. Typical values for G and R are 1 and 0.2, respectively. A value for H of 60 operating hours was chosen since this is a wartime flying estimate. In peacetime, normal operating hours per month would be between 30 and 40 hours. Realistic sparing levels must be based on the wartime requirement. Substituting these values (G = 1, R = 0.2, H = 60) *into the above equation yields:*

$$\frac{\text{Spares}}{\text{Op Unit}} = \frac{(1)(60)T}{M(0.8)} = \frac{75T}{M} \qquad \text{Equation 11.1}$$

Figure 3 is a plot of this equation. It is apparent that a high MTBF (above 600 operating hours) the number of spares/operating unit is relatively insensitive to the turnaround time, when $0 < T < 1.5$ months. The Navy and Air Force both believe that a T of 1.5 months is reasonable for TACAN equipment. The curve of T = 4.5 is shown to be indicative of the required spares/operational unit for carrier operation.

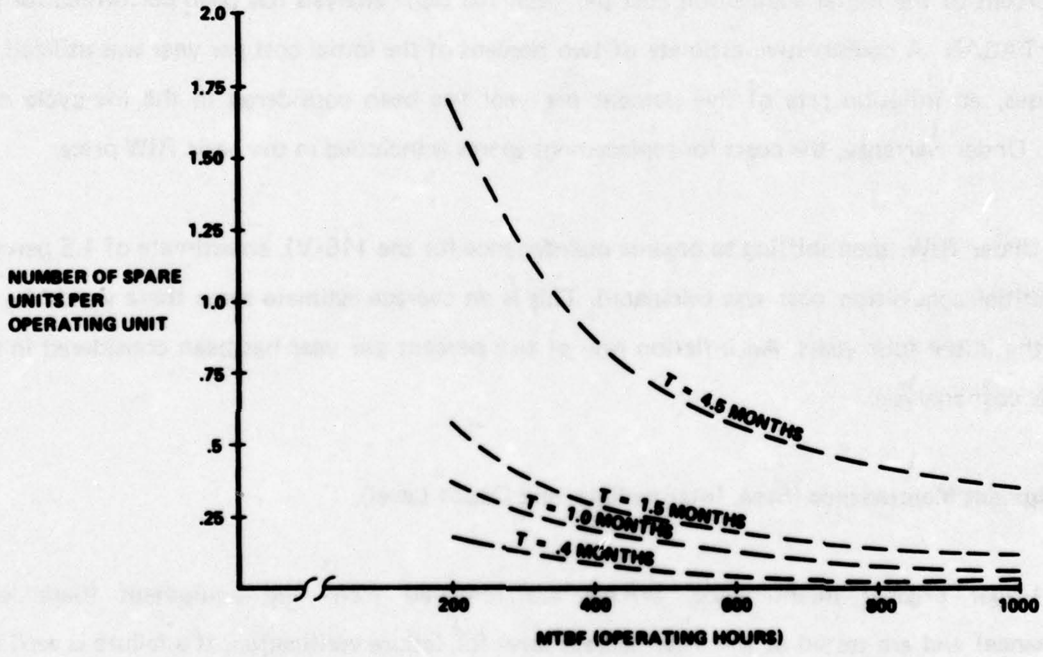

Figure 3. Number of Spare Units Required Under RIW

The results require a 14 percent rate of unit spares (14 spare units per 100 operating units), based on an MTBF of 800 hours for the 118(V) and a total turnaround time of 45 days (T = 1.5 months).

The RIW contract for the 118(V) will probably require the transition from RIW to organic maintenance in 1982. On the assumption that the Navy will follow the Air Force (if and when they shift), additional money will have to be provided by the Navy for spares, PGSE, training, and data requirements. Because this problem has been considered by the Air Force in their procurement, the PGSE, training, and data under RIW will not be scrapped and there will only be incremental costs incurred.

3. Replacement Spares

Under organic maintenance, the replacement spares estimates are based on the MTBF and the replacement rates based on the Level of Repair (LOR) analysis. For the 84(V), the estimate is three percent of the initial acquisition cost per year. No LOR analysis has been performed for the 118(V) TACAN. A conservative estimate of two percent of the initial cost per year was utilized. In both cases, an inflation rate of five percent per year has been considered in the life-cycle cost analysis. Under warranty, the costs for replacement spares is included in the basic RIW price.

Under RIW, then shifting to organic maintenance for the 118(V), an estimate of 1.5 percent of the initial acquisition cost was calculated. This is an average estimate since there would be no cost in the initial four years. An inflation rate of five percent per year has been considered in the life-cycle cost analysis.

4. Equipment Maintenance (Base, Intermediate, and Depot Level)

Under organic maintenance, WRA's are removed from the equipment (base level maintenance) and are tested at the intermediate level for failure verification. If a failure is verified, the WRA is either sent to a depot for repair or the subassembly causing failure is identified and replaced. The failed subassembly is either discarded or sent to the depot for repair, depending upon the results of LOR analysis.

Under RIW, base maintenance involves unit removal, replacement, and failure verification testing. The unit is either repaired at the base for special cases (e.g., fuse replacement, light bulb burnouts, etc.) or is sent to the contractor for repair. No maintenance actions upon subassemblies are performed by military technicians when RIW is in force.

The following analysis provides the average cost to pull and repair per operating unit per year under organic maintenance. Most of the parameters, with the exception of MTBF, can be treated as constants. The results, which are plotted in Figure 4, are applicable to either the 84(V) or the 118(V) TACAN under organic maintenance. The data inputs used in developing these results are listed in Table 3. All estimates are based on Navy and Air Force estimates. Dollar rates are quoted in 1976 dollars. An inflation rate of five percent per year was utilized for this component of the life-cycle cost.

TABLE 3. ESTIMATES USED TO DETERMINE ORGANIC MAINTENANCE AVERAGE COST

Parameter	Value
False removal rate (F_R)	0.2
Ground-to-Air ratio (G_A)	1:1
Flight hours/month/aircraft (H)	60 hrs
Manhours required to pull or replace and test at base level (T_B)	1.0 hr
Manhours required to test and repair at the intermediate level (T_I)	1.5 hrs
Manhours required to test and repair at the depot level (T_D)	2.0 hrs
Base labor cost/hour (R_B)	$14.84
Intermediate level labor cost/hr	$14.84
Intermediate cost to test a good pull (T_{G_I})	$22.26
Intermediate level average material and transportation cost	$ 4.67
Intermediate level total cost/hr (R_I)	$19.51
Depot level labor cost/hr	$26.60
Depot cost to test a good pull (T_{G_D})	$39.90
Depot level average material and transportation cost	$14.07
Depot level labor total cost/hr (R_D)	$40.67
Intermediate repaired vs. received rate (R_R)	60%

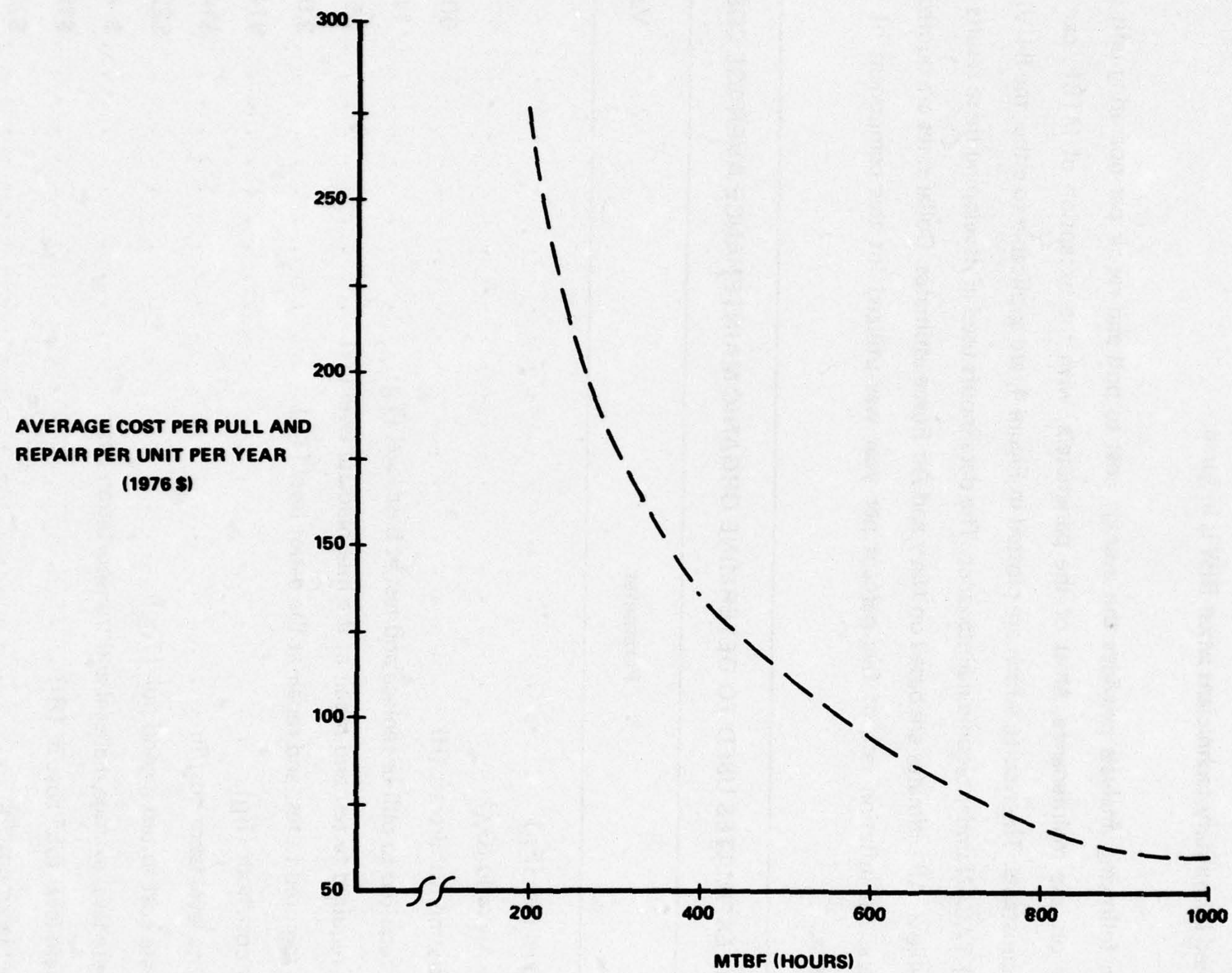

Figure 4. Organic Maintenance

AVERAGE COST TO PULL AND REPAIR/UNIT/YEAR

1. The expected number of repairs/unit/year (N) is based on operating hours and MTBF and is calculated as follows:

$$N = \frac{12(G_A)(H)}{MTBF}$$

$$N = \frac{12(1)(60)}{MTBF} \qquad \text{Equation 15.1}$$

$$N = \frac{720}{MTBF}$$

2. The estimated number of pulls/unit/year (P) is based on the expected number of repairs/unit/year (N) and the false removal rate (F_R) and is calculated as follows:

$$P = \left(\frac{1}{1 - F_R}\right) \cdot (N)$$

$$P = \left(\frac{1}{1 - 0.2}\right)\left(\frac{720}{MTBF}\right)$$

$$P = 1.25\left(\frac{720}{MTBF}\right) \qquad \text{Equation 15.2}$$

$$P = \frac{900}{MTBF}$$

3. The labor cost for each pull/replace at the base level (LC_B) involves the time required for the action (T_B) and the labor rate (R_B) and is as follows:

$$LC_B = (T_B)(R_B)$$

$$LC_B = (1)(\$14.84) \qquad \text{Equation 15.3}$$

$$LC_B = \$14.84$$

4. Therefore, the total cost for the estimated number of pulls/unit/year (P) and the labor cost for each pull/replace at the base level (LC_B) is:

$$TC_B = (P)(LC_B)$$

$$TC_B = \left(\frac{900}{MTBF}\right)(\$14.84) \qquad \text{Equation 16.1}$$

$$TC_B = \frac{\$13{,}356}{MTBF}$$

5. The total cost for test and repair at the Intermediate level (TC_I) involves the time required to effect the repair (T_I), the total labor rate (R_I), including material and transportation costs and is as follows:

$$TC_I = (T_I)(R_I)$$

$$TC_I = (1.5)(\$19.51) \qquad \text{Equation 16.2}$$

$$TC_I = \$29.27$$

6. The total cost for test and repair at the depot level (TC_D) involves the time required to effect repair (T_D), the labor rate, material, and transportation (R_D) and is as follows:

$$TC_D = (T_D)(R_D)$$

$$TC_D = (2)(\$40.67) \qquad \text{Equation 16.3}$$

$$TC_D = \$81.34$$

7. The total cost to repair (TC_R) is based on the cost to repair at the intermediate level (TC_I), the cost to repair at the depot level (TC_D), the number of expected repairs (N), and the repair rates (R_R) and is as follows:

$$TC_R = (TC_I)(N)(R_R) + (TC_D)(N)(1 - R_R)$$

$$TC_R = (\$29.27)\left(\frac{720}{MTBF}\right)(0.6) + (\$81.34)\left(\frac{720}{MTBF}\right)(0.4) \qquad \text{Equation 16.4}$$

$$TC_R = \frac{\$36{,}068}{MTBF}$$

8. The total cost to test a good pull (TC_{GP}) is based on the cost to test a good unit, which has an intermediate maintenance component (T_{G_I}) and a depot maintenance component (T_{G_D}), expected number of units pulled (P), the false removal rate (F_R), and the Repair detection rate (R_R) and is as follows:

$$TC_{GP} = (T_{G_I})(P)(R_R)(F_R) + (T_{G_D})(P)(1 - R_R)(F_R)$$

$$TC_{GP} = (22.26)\left(\frac{900}{MTBF}\right)(0.6)(0.2) + (39.90)\left(\frac{900}{MTBF}\right)(0.4)(0.2) \qquad \text{Equation 17.1}$$

$$TC_{GP} = \frac{\$5{,}277}{MTBF}$$

9. Therefore, the total cost to pull (TC_{PR}) and repair/unit/year is the sum of the total cost to pull and test at the base level (TC_B), (Eq. 16.1), the total cost to repair (TC_R) (Eq. 16.4), and the total cost for test of a good pull (Eq. 17.1) and is as follows:

$$TC_{PR} = TC_B + TC_R + TC_{GP}$$

$$TC_{PR} = \frac{\$13{,}356}{MTBF} + \frac{\$36{,}068}{MTBF} + \frac{\$5{,}277}{MTBF} \qquad \text{Equation 17.2}$$

$$TC_{PR} = \frac{\$54{,}701}{MTBF}$$

A curve of this equation is shown in Figure 4 (page 14).

5. Transportation

Under organic maintenance, the cost of transporting a WRA or subassembly to a depot for maintenance has been included in the equipment maintenance costs.

Under RIW, the government pays for transportation separately. The average one-way cost of shipping a WRA is estimated as $32. This estimate is based on Navy and Air Force data. An inflation rate of five percent per year has been considered in this portion of the life-cycle cost analysis.

6. Training

Under both organic maintenance and RIW, an estimate of 50 bases has been utilized. Under organic maintenance, the required training is for one man per base per year to be trained for a two-week period. This estimate includes the training required for intermediate level repair. Depot level training costs are included in depot labor costs. The $180 thousand already invested in 84(V) TACAN training has not been included in the life-cycle cost for that equipment.

Under RIW, the required training is one man per base per year to be trained for one week.

The estimated cost per week of training is $600 per man. A five percent inflation rate was used in this portion of the life-cycle cost analysis.

7. PGSE

Under organic maintenance, the cost for PGSE for the 84(V) TACAN equipment is quite expensive. However, the Navy has already invested $3.4 million in intermediate and depot maintenance PGSE. No additional PGSE is required.

Under warranty, only a simple test set at each base is required. The unit cost of this test set is $5000.

In the case of initial RIW, then a shift to organic maintenance, there will be extra costs incurred, since base test devices costing $15,000 per set are required.

Under the options that lead to eventual organic maintenance of the 118(V), an estimate of $200K has been included to modify the PGSE depot software to handle the 118(V). The basic PGSE that exists for the 84(V) will suffice with modification for the 118(V). Inflation has not been considered in these estimates.

In all cases, an estimate of three percent of the PGSE investment has been taken as the yearly cost to maintain PGSE. An inflation rate of five percent per year was used in calculating this component of the life-cycle cost.

8. Documentation

The costs of data publications are based on Navy and Air Force estimates. No inflationary factor was considered in this portion of the life-cycle cost analysis.

9. Inventory Management

Costs for inventory management have been included in the equipment maintenance estimates under organic maintenance. Under RIW, these costs are included in the RIW price.

10. RIW Price

The existing contract between Air Force and Collins Radio provides for a RIW price per year of 4.7 percent of acquisition cost for four years. It has been estimated that an average price of 5.45 percent of acquisition cost would be required for the years after the initial four. This figure is based on an inflation rate of five percent. An average inflation rate of greater than five percent would require a change in the RIW price.

RESULTS OF NAVY LIFE-CYCLE COST ANALYSIS

A graphic representation of the life-cycle cost comparison of the 84(V) and 118(V) TACAN equipments procured under various contracts as shown in Figure 5. The graph curves are based on the MTBF being constant and as contractually specified.

A comparison of the life-cycle costs with the MTBF varying as much as ±100 hours and with both TACAN equipments under totally organic maintenance is shown in Figure 6. This graph shows that a ±100-hour variation in the MTBF results in a variation of approximately $750 for the 118(V) TACAN and a variation of $2,750 for the 84(V) TACAN; that is that TACAN equipments failing to meet the contractually specified MTBF increase the life cycle costs of 84(V) significantly more than those of the 118(V).

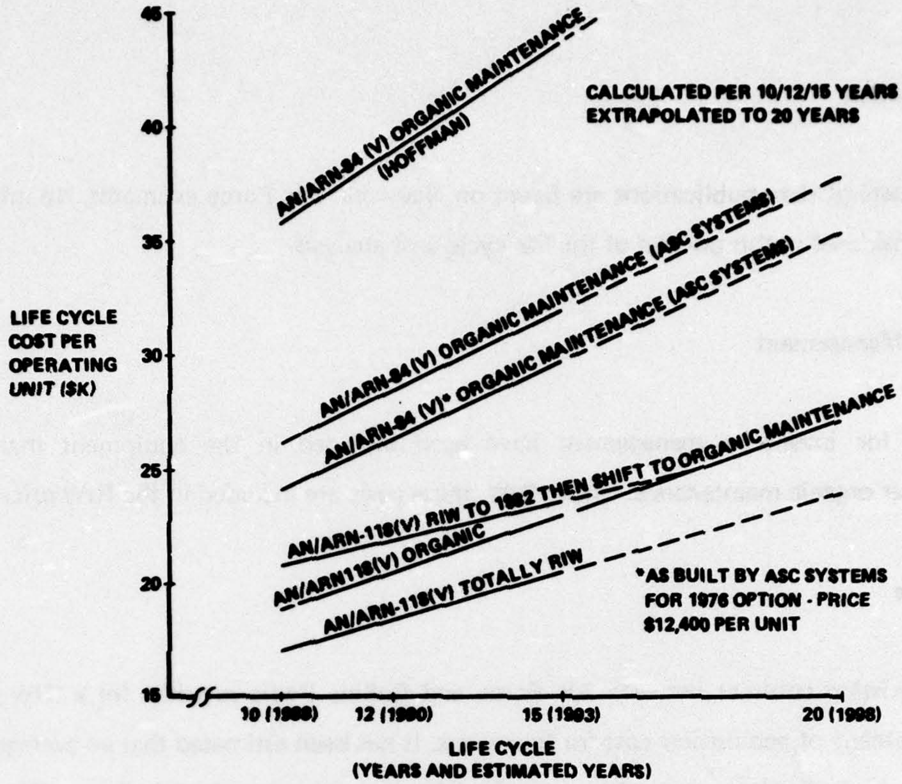

Figure 5. Comparative TACAN Life-Cycle Cost per Operating Unit

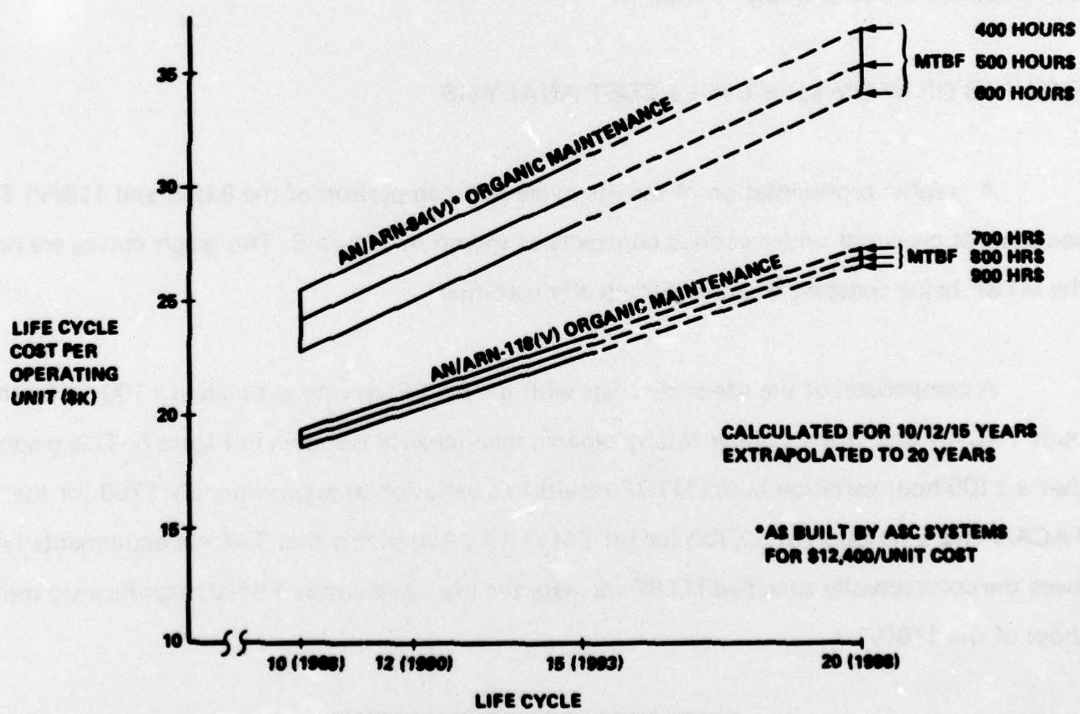

Figure 6. Life-Cycle Cost of AN/ARN-84(V) and AN/ARN-118(V) under Organic Maintenance

Figure 7 is a comparison of the 118(V) under RIW to 1982 (then shifting to organic maintenance) with the 84(V) under total organic maintenance. This curve illustrates the point that the MTBF of the 118(V) is guaranteed. (Failure to achieve the 800 operating-hour MTBF will force the contractor to provide more spare units. The contractor has a strong incentive to ensure that the 118(V) TACAN achieves a MTBF of 800 operating hours.)

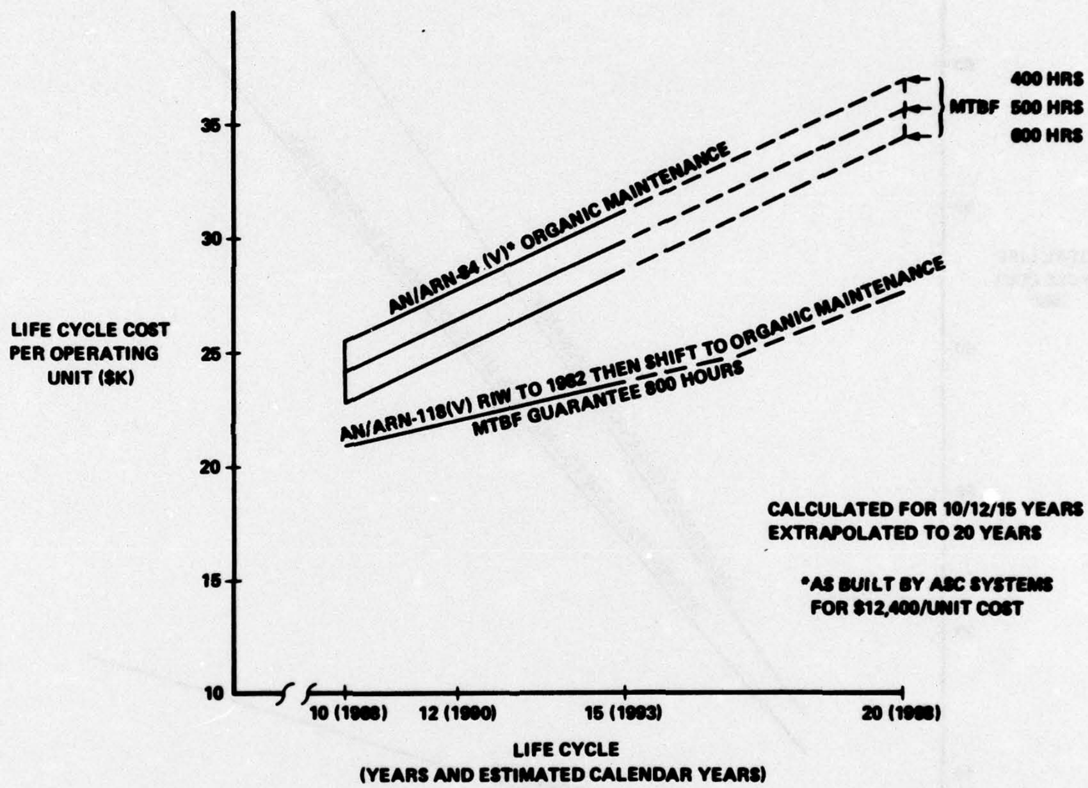

Figure 7. Life-Cycle Cost for AN/ARN-84(V) TACAN under Organic Maintenance Compared to AN/ARN-118(V) under RIW/Organic Maintenance

Figure 8 presents a total life-cycle cost (at the 12-year point) comparison for the 84(V) under organic maintenance compared to 118(V) under RIW and then shifting to organic maintenance. The number of units to be purchased in the future is a variable. Figure 9 presents the same data over a life cycle of 15 years.

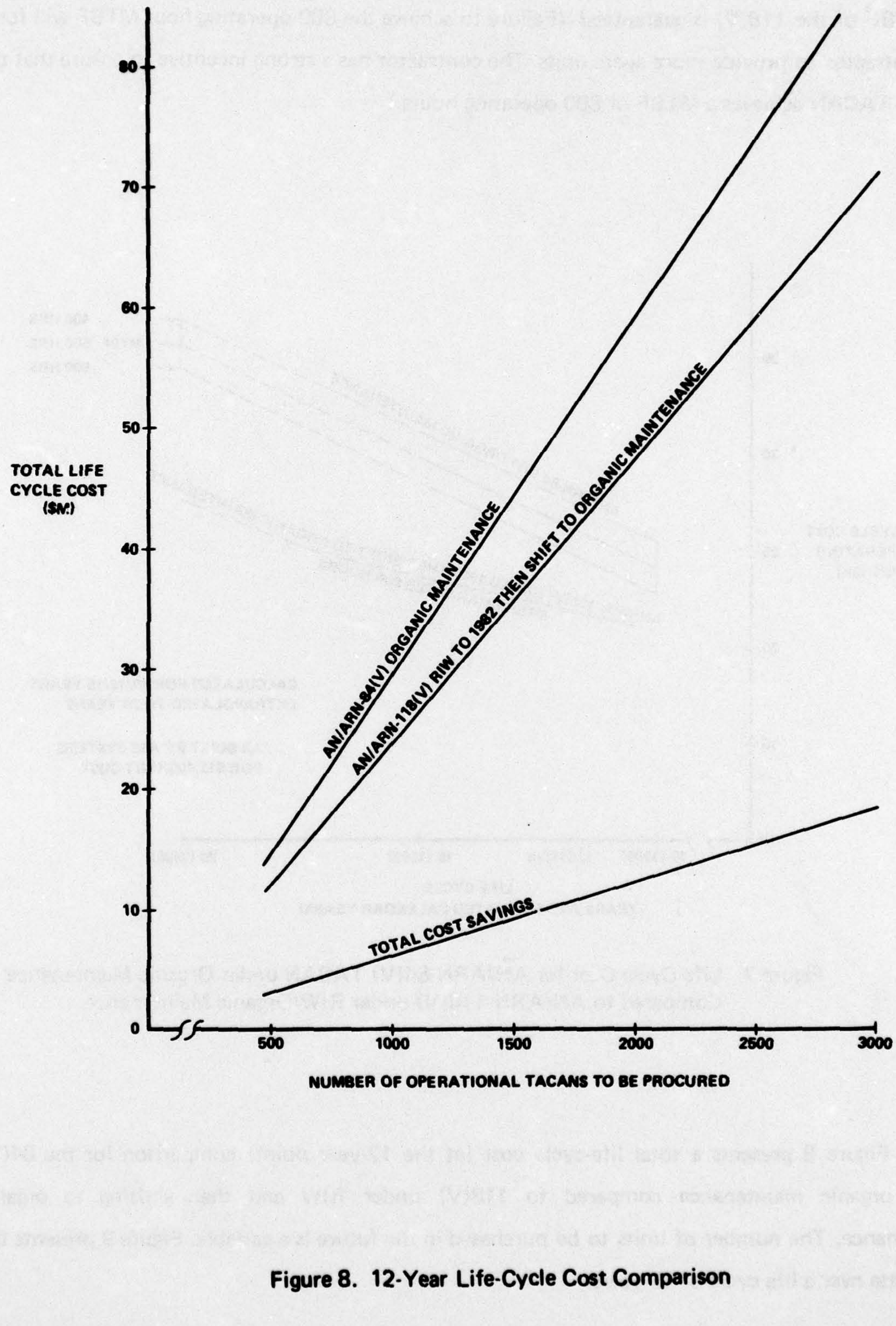

Figure 8. 12-Year Life-Cycle Cost Comparison

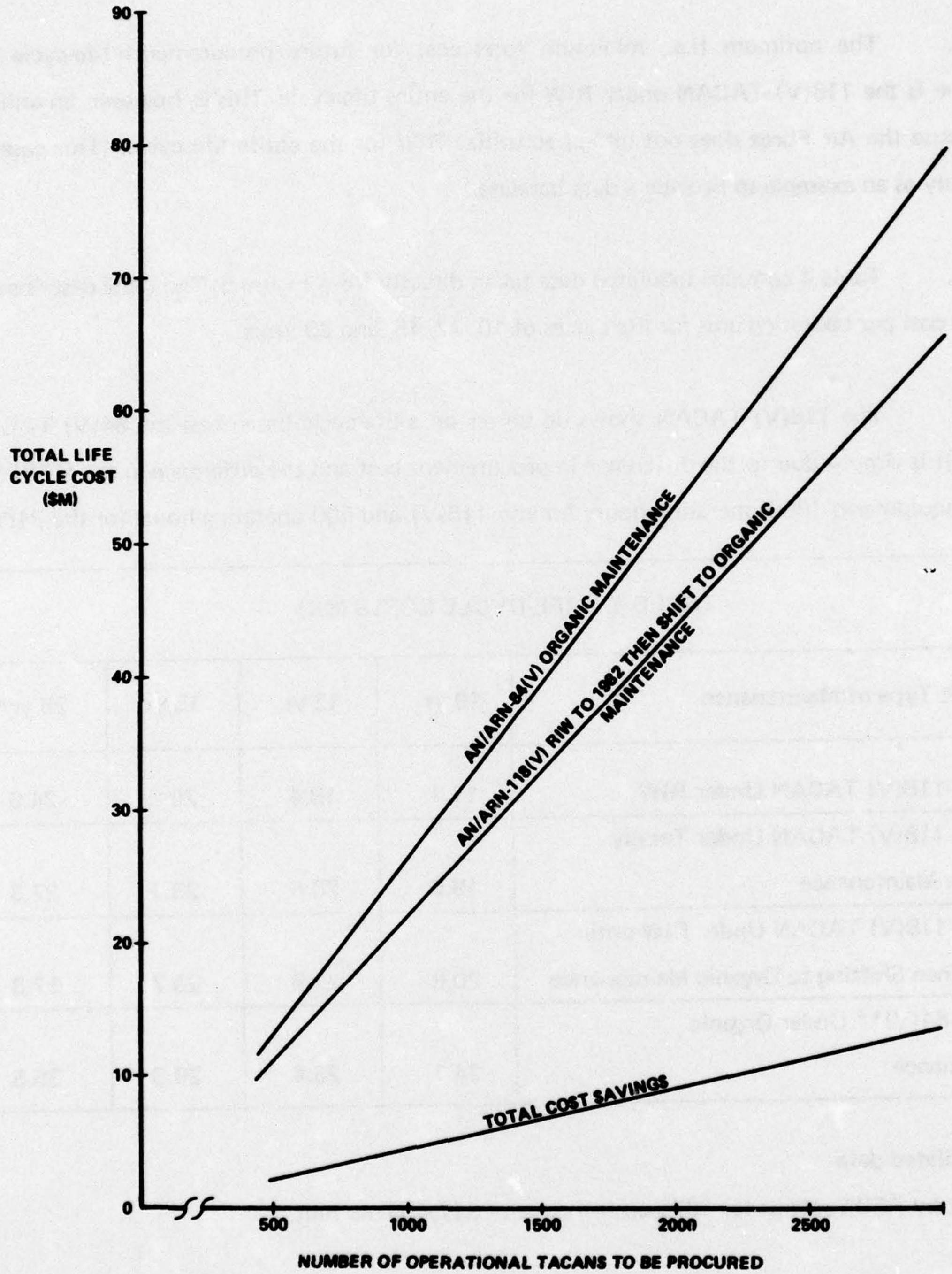

Figure 9. 15-Year Life-Cycle Cost Comparison

The following results are shown in Figures 5 through 9:

a. The optimum (i.e., minimum total cost for future procurement) life-cycle cost alternative is the 118(V) TACAN under RIW for the entire life cycle. This is, however, an unlikely case because the Air Force does not intend to utilize RIW for the entire life cycle. (This case was shown only as an example to provide a data baseline.)

b. Table 4 contains tabulated data taken directly from Figure 5. The table describes the life-cycle cost per operating unit for life cycles of 10, 12, 15, and 20 years.

c. The 118(V) TACAN shows up better on a life-cycle basis than the 84(V) TACAN. This result is simply due to the difference in procurement cost and the difference in the MTBF's of the two equipments [800 operating hours for the 118(V) and 500 operating hours for the 84(V).]

TABLE 4. LIFE-CYCLE COSTS ($K)

TACAN & Type of Maintenance	10 yr	12 yr	15 yr	20 yr*
AN/ARN-118(V) TACAN Under RIW	17.1	18.4	20.5	24.0
AN/ARN-118(V) TACAN Under Totally Organic Maintenance	19.0	20.6	23.1	27.3
AN/ARN-118(V) TACAN Under RIW until 1982 Then Shifting to Organic Maintenance	20.8	21.9	23.7	27.3
AN/ARN-84(V)** Under Organic Maintenance	24.1	26.4	29.8	35.5

*Extrapolated data

**As built by ASC Systems for 1976 option price of $12,400 per unit.

d. The 118(V) TACAN life-cycle cost under totally organic maintenance, and the cost under RIW until 1982 and then shifting to organic maintenance show little difference.

e. The life-cycle cost of the 118(V) TACAN is reasonably insensitive to variations in the MTBF.

f. As the time estimate of the life cycle expands, the savings in favor of the 118(V) will continue to increase. The difference between the slopes of the life-cycle cost curves for the 84(V) TACAN and the 118(V) TACAN is due to the difference in the MTBF's of the two equipments [500 operating hours for the 84(V) TACAN and 800 operating hours for the 118(V) TACAN]. The most significant point is that there can be no crossover point since the 84(V) has a higher initial cost and higher maintenance costs.

g. The continuation of procurement of the 84(V) TACAN from Hoffman is not economical (Navy will not exercise its 1976 option with Hoffman).

h. The long-term savings that can be achieved by procuring the 118(V) TACAN are substantial. Table 5 provides some point estimates.

TABLE 5. POTENTIAL SAVINGS ($M)

Number of Operational TACANs to be Procured	10 yr	12 yr	15 yr	20 yr
1000	3.30	4.50	6.10	8.20
1500	4.95	6.75	9.15	12.30
2000	6.60	9.00	12.20	16.40

The data in Table 5 is for the case of the 118(V) TACAN under RIW then shifting to organic maintenance compared to the 84(V) TACAN under totally organic maintenance. If the case of the 118(V) TACAN under organic maintenance were utilized, the results would be more in favor of the 118(V) TACAN.

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CHAPTER III

U.S. COAST GUARD LIFE-CYCLE COST ANALYSIS

BACKGROUND

The 84(V) TACAN has been proposed by the Navy as the primary TACAN system for both the Navy and the Coast Guard. This section has been provided to analyze a Coast Guard request for procurement of the 118(V). The material has been generally treated in previous sections, but specific Coast Guard needs will be discussed here.

The Coast Guard has stated that the 84(V) TACAN is too complex and has features that are not required by the Coast Guard even when the Coast Guard aircraft are integrated into the Navy during wartime. Additionally, the Coast Guard has found that due to lack of appropriate PGSE for the 84(V), they are returning units to the depot about twice as frequently as would be normally expected for a device with a MTBF of 500 operating hours.

The deployment of Coast Guard aircraft is such that it would require a heavy investment in PGSE to service the 84(V) on an organic basis within the Coast Guard.

The Coast Guard has two older TACAN's (AN/ARN-21 and AN/ARN-52) in service at the present time. The Coast Guard has stated that both of these equipments should be replaced. They have reported that the AN/ARN-21 is unsupportable, and that the AN/ARN-52 has been plagued with maintenance problems. Its MTBF is approximately 50 hours.

The Coast Guard has requested the Navy to procure the 118(V) TACAN's for the Coast Guard. The Coast Guard desires that the contract be, in effect, under an RIW for the entire life cycle of the equipment. If the contractor phases out of the 118(V) TACAN program in 1982, the Coast Guard will look to the Air Force depots to assume the obligations of the RIW.

COAST GUARD REQUIREMENT

The Coast Guard has 193 aircraft of various types that need replacement of their TACAN equipment. These aircraft are deployed at 30 bases, with as few as one aircraft per base. The utilization of the 84(V) and associated PGSE will require a significant investment in spare parts, men, and training. A comparative life-cycle analysis for the Coast Guard case follows. The results of Chapter II, The Life-Cycle Cost Analysis, are not directly applicable to the Coast Guard case due to the structure of the Coast Guard forces.

LIFE-CYCLE COSTS DATA FOR COAST GUARD TACAN ANALYSIS

The ten cost categories described in Table 1 are the same categories used for Coast Guard analysis. However, the input data has been modified to fit the Coast Guard problem.

Table 6 describes the cost factors in the life-cycle cost analysis for the Coast Guard. The most significant cost item is the PGSE. The requirement to outfit 30 bases and 20 intermediate repair bases yields a total cost of $4.45 million. This converts to a per operating unit cost of $23.06 thousand, which is almost twice the hardware procurement cost of each operating unit.

RESULTS OF COAST GUARD LIFE-CYCLE COST ANALYSIS

Figures 10 and 11 present the results of the life-cycle cost comparison between the 84(V) under organic maintenance and the 118(V) under RIW. The large difference is due to the large cost incurred for PGSE under organic maintenance, while only a relatively minor PGSE cost is incurred under RIW ($4.45 million for PGSE for the 84(V) and $.150 million for PGSE for the 118(V)). The savings that can be achieved by procuring the 118(V) TACAN for the Coast Guard instead of the 84(V) TACAN will amount to $7.5 million over a 12-year life cycle. If a 15-year life cycle is considered, the savings will amount to $8.7 million.

TABLE 6. COST FACTORS IN COAST GUARD LIFE-CYCLE COST ANALYSIS

Cost Factor Categories	Probable Maintenance Philosophies	
	AN/ARN-84(V) Organic Maintenance	AN/ARN-118(V) RIW (See note 1)
Acquisition Cost Cost/Unit ($K) (See note 2)	12.4 ASC Systems	10.4
Spares/operational unit (see note 3)	30.5%	0.20 spare unit/operating unit or 20%
Replacement Spares (See note 4)	4%/year	Included in RIW price
Equipment Maintenance (See note 5)	Data from Figure 4	Included in RIW price
Transportation	Included in equipment maintenance cost	Average $32 per one-way trip
Training	1 person/year/base for 2 weeks $600/week	1 person/year/base for 1 week $600/week
PGSE (See note 6)	$15,000 per base $4 million (intermediate) 0 Depot (already exists)	$5,000 per base
PGSE Support	3%/year	3%/year
Data Publications	2% of acquisition cost	$475/operational unit
Inventory Management Costs	Included in equipment maintenance costs	Included in RIW price
RIW price/year ($/year) (See note 7)	0	4.7% of 9.4K = $.44K until 1982 After 1982 5.45%/year

NOTES

NOTE 1. Interviews with Coast Guard personnel have shown that the Coast Guard will want the contract to look like an RIW for the entire life cycle of the AN/ARN-118(V). This can be accomplished if the Air Force depots assume the responsibility performed by the contractor.

NOTE 2. The \$12.4K price is based on a recently exercised option for 123 equipments from ASC Systems. The unit price of the AN/ARN-118(V) is based on an Air Force contract price of \$9.4K plus \$1.0K for aircraft modifications. No provision is made for a digital converter. The Coast Guard desires to utilize the ARINC Format since the rest of the avionics that they use are commercial and utilize ARINC Format.

NOTE 3. These data are based on the MTBF (500 hours stated for the AN/ARN-84(V) and 800 operating hours for the AN/ARN-118(V)), and a spares sufficiency rate of 95 percent. Normal turnaround times for organic or warranty maintenance were considered. An additional constraint is that one WRA or unit is required at each base. For the AN/ARN-118(V), the results of Equation 6.1 would require only 30 units (15.5 percent). However, this would only satisfy the one unit/base requirement. An additional nine units (4.5 percent) are required to satisfy pipeline requirements.

NOTE 4. Replacement spares estimates are based on MTBF and replacement/throughout rates based on the Level of Repair analysis.

NOTE 5. These estimates include base, intermediate, and depot maintenance. Details are provided in Chapter II, page 14.

NOTE 6. The Coast Guard estimates that they will have 20 intermediate level repair sites which will require PGSE with an estimated acquisition cost of \$200,000/unit. One each will be required for each intermediate repair site.

NOTE 7. A RIW price of 4.7 percent per year would apply through 1982. After 1982, price would increase in line with inflation statistics. An inflation rate of five percent is used in estimating price escalation after 1982. Use of this estimate as shown in the table is very conservative since a shift to Depot Maintenance by the Air Force would create a price of less than \$150 (1976 \$) average cost per pull and repair per unit/per year. This estimate includes transportation costs.

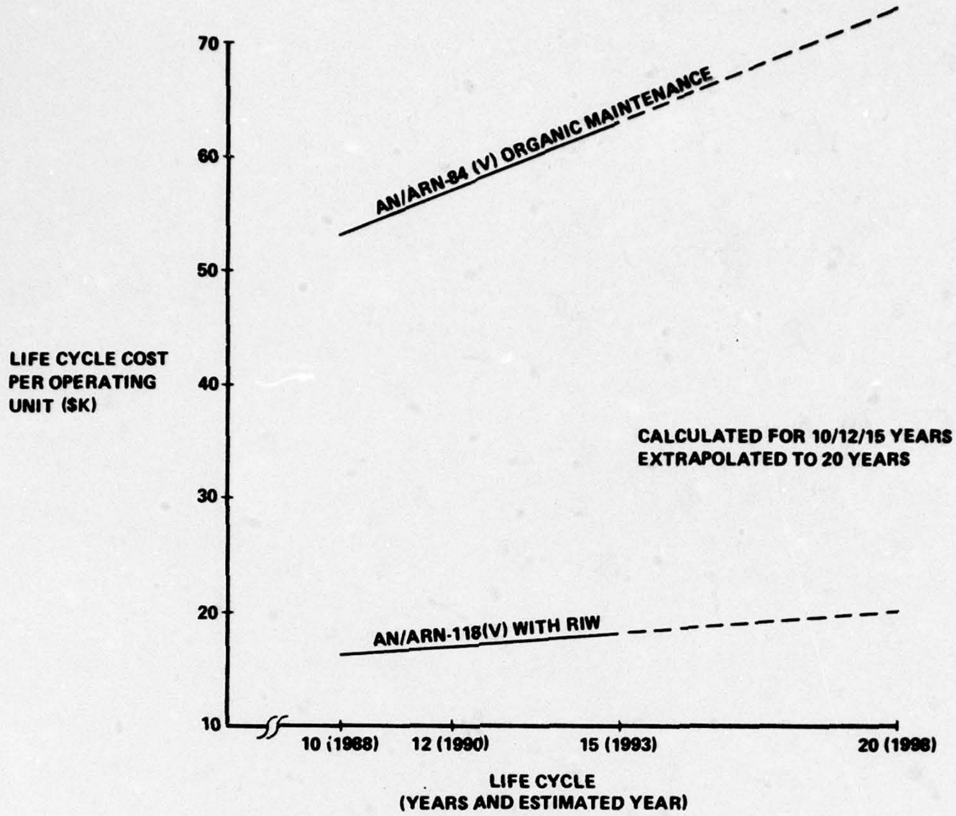

Figure 10. Life-Cycle Cost Comparison for Coast Guard

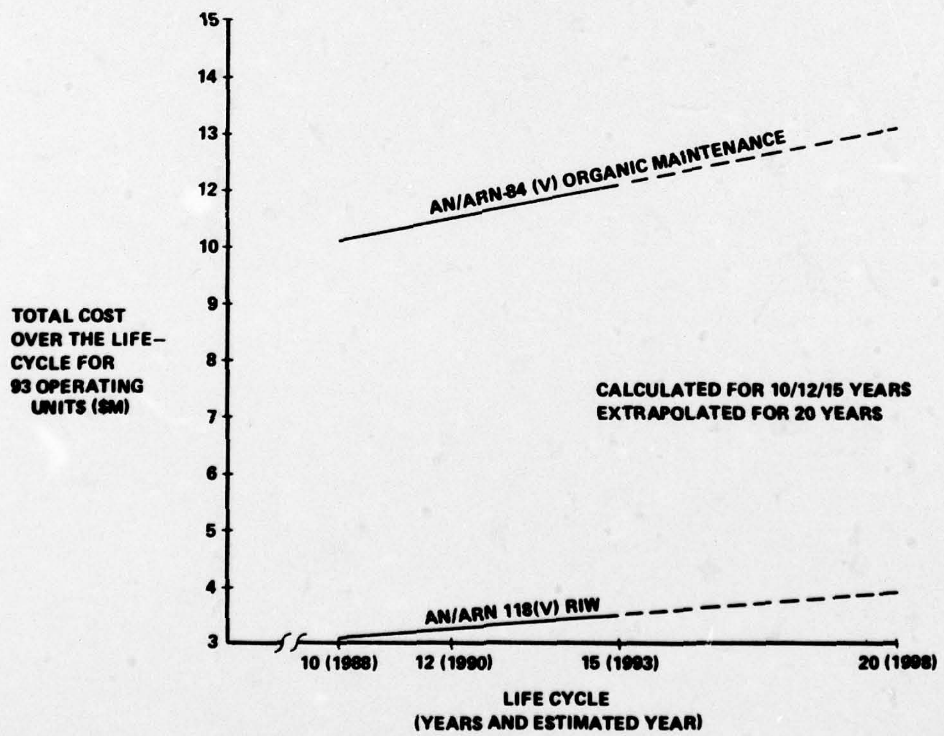

Figure 11. Coast Guard Total Cost Comparison over the Life Cycle

APPENDIX A

WARRANTY CONCEPT FOR AN/ARN-118(V) TACAN

This Appendix describes the important features of the Reliability Improvement Warranty (RIW) contract on the AN/ARN-118(V) TACAN between the Air Force and Collins Radio Corporation.

WARRANTY STATEMENT

Under the RIW contract for the AN/ARN-118(V) TACAN between Air Force and Collins Radio, the contractor warrants that the TACANs furnished under the contract will be free from defects in design, material, and workmanship and will operate in its intended environment for a specified period.

WARRANTY COVERAGE PERIOD

The period of warranty coverage can be stated in years and/or operating hours. The specific coverage in the AN/ARN-118(V) RIW contract is four years from 31 December of the year in which the specific TACAN is accepted by the Air Force. After the four-year period, the Air Force can transit to organic maintenance or renegotiate for continuation of the warranty.

MTBF GUARANTEE VALUES

The RIW has broken the four-year period into three guarantee periods. Table A-1 shows the MTBF guarantee for these three periods.

TABLE A-1. MTBF GUARANTEE PERIODS

Period	Time	MTBF
1	1st year equipments	500
2	2nd year equipments	625
3	after 2 years equipments	800

The Air Force expects to achieve an operational MTBF of 800 hours after two years. Because the Navy would be coming into the program after the two-year period, they can anticipate receiving equipment with an 800-hour MTBF guarantee.

EXCLUSIONS

The AN/ARN-118(V) warranty contains standard exclusions such as failure due to aircraft fire or explosion, combat damage, and acts of God. Additionally, failures due to mistreatment (external physical damage) are excluded.

TURNAROUND TIME

The AN/ARN-118(V) RIW contains a basic guarantee for a 15-day average turnaround time by the contractor within his plant. A liquidated damage penalty can be assessed if the contractor fails to achieve the 15-day average turnaround time. The 15-day average turnaround time was specified to control the number of spare units required. Contractor failure to meet the 15-day requirement could possibly result in spares insufficiency, which in turn may result in reduced aircraft readiness.

ECONOMIC PRICE ADJUSTMENT

The prices quoted by Collins took into account reasonable estimates of inflation. The Air Force has agreed to adjust the price of the warranty for abnormal price fluctuations based on Bureau of Labor Statistics (BLS) national indexes for labor and material.

COST OF WARRANTY

The cost of the warranty is 4.7 percent of the acquisition cost per year. There will be no adjustment in this cost if prices do not escalate faster than five percent/year. This figure excludes transportation costs which are paid by the government.

EXTENSION OF WARRANTY

Based on experience, the Air Force believes that they can extend the warranty if the 800-hour MTBF has been achieved. The contractor's bid price of 4.7 percent/year is consistent with a MTBF guarantee of 800 hours. It must be realized that any Navy procurement would be small compared to Air Force and that the Navy would probably be forced to shift to organic maintenance if the Air Force shifts. The Air Force currently intends to shift to organic maintenance in 1982 for the AN/ARN-118(V) TACAN.

*U.S. GOVERNMENT PRINTING OFFICE: 1976 240-824/063 1-3